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Određivanje slatkovodnih mahovnjaka (Bryozoa)

Diplomski rad

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Division of Biology

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Identification key for freshwater bryozoans (Bryozoa)

Graduation Thesis

Zagreb, 2009.

Ovaj rad, izrađen u Zoologijskom zavodu Biološkog odsjeka Prirodoslovno–matematičkog fakulteta Sveučilišta u Zagrebu, pod voditeljstvom dr. sc. Emmy Wöss, suvoditeljstvom doc. dr. sc. Tatjane Bakran-Petricioli i pomoćnim voditeljstvom dr. sc. Maje Novosel, predan je na ocjenu Biološkom odsjeku Prirodoslovno–matematičkog fakulteta Sveučilišta u Zagrebu radi stjecanja zvanja dipl. prof. biologije.

This Graduation Thesis, has been made in the Department of Zoology of Division of Biology of Faculty of Science of University of Zagreb, under the supervision of Emmy Wöss, Ph.D., subsupervision of Asst. Prof. Tatjana Bakran-Petricioli, Ph.D. and assistant supervision of Maja Novosel, Ph.D., and was given to be evaluated to the Division of Biology of Faculty of Science of University of Zagreb in order to acquire proffesion Professor of Biology.

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University of Zagreb
Faculty of Science
Division of Biology

Graduation Thesis

Identification key for freshwater bryozoans (Bryozoa)

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Freshwater bryozoans comprise a small but important group of benthic invertebrates, often an abundant component in lentic as well as in lotic water bodies. They are sessile and form colonies which usually do not overwinter. However, they form chitinised statoblasts as resting stages for reproduction and dispersal. Statoblasts include floating (floatoblasts, leptoblasts) and sessile (sessoblasts, piptoblasts) forms and are the important tool for species distinction. So far, only 19 species have been recorded in Europe, and 88 species worldwide. In the course of the first survey on freshwater bryozoans on the territory of the Republic of Croatia, eleven species were found: ten belong to the Class *Phylactolaemata* (*Fredericella sultana*, *Plumatella casmiana*, *Plumatella emarginata*, *Plumatella fruticosa*, *Plumatella fungosa*, *Plumatella geimermassardi*, *Plumatella repens*, *Hyalinella punctata*, *Lophopus crystallinus* and *Cristatella mucedo*) and one to the Class *Gymnolaemata* (*Paludicella articulata*). This study represents a detailed description of these species with special focus on the investigation of statoblasts. The identification of the resting stages include scanning electron microscopy for detailed anaylsis of the statoblast valves.

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Određivanje slatkovodnih mahovnjaka (Bryozoa)

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Slatkovodni mahovnjaci obuhvaćaju malu, ali važnu skupinu bentičkih beskralješnjaka, koji su česti kako u lentičkim tako i u lotičkim vodenim staništima. Sesilni su, ali njihove kolonije ne prezimljavaju. Ipak, formiraju hitinizirane statoblaste kao stadije mirovanja za razmnožavanje i rasprostranjivanje. Statoblasti uključuju plutajuće (floatoblasti, leptoblasti) i sesilne (sesoblasti, piptoblasti) oblike, a važni su za određivanje vrsta. Samo 19 vrsta slatkovodnih mahovnjaka je do sada nađeno u Europi, a u svijetu oko 88. Tijekom ovog prvog istraživanja slatkovodnih mahovnjaka na teritoriju Republike Hrvatske, nađeno je 11 vrsta mahovnjaka: deset ih pripada razredu *Phylactolaemata* (*Fredericella sultana*, *Plumatella casmiana*, *Plumatella emarginata*, *Plumatella fruticosa*, *Plumatella fungosa*, *Plumatella geimermassardi*, *Plumatella repens*, *Hyalinella punctata*, *Lophopus crystallinus* i *Cristatella mucedo*), a jedna razredu *Gymnolaemata* (*Paludicella articulata*). U ovom radu detaljno su opisane ove vrste s posebnim osvrtom na istraživanje statoblasta. Određivanje statoblasta uključuje mikroskopiranje na skenirajućem elektronskom mikroskopu u svrhu detaljne analize njihovih vanjskih obilježja.

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Contents

1. INTRODUCTION

1.1 General features of freshwater bryozoans

Bryozoans are benthic, suspension-feeding invertebrates that are widely distributed in freshwater and marine habitats. Very often, freshwater bryozoan species can be found in quiet waters and eutrophic habitats at shallow depths. The most favourable substrata are those which are relatively fixed, old and inert. Less favourable substrata include materials that are slimy, actively decomposing, or surfaces that can be turned around by turbulent water.

Freshwater bryozoan colonies are variable in form, ranging from chitinized, adherent or upright branching colonies through to gelatinous sacs, ribbons and spheres. They are composed of genetically identical units called zooids (Wood and Okamura 2005).

Zooids in freshwater bryozoans are not separated by distinct walls, as in marine bryozoans. However, zooids of freshwater bryozoans can have septa which separate the single zooids in some species, but they share a continuous fluid–filled *body cavity* (*coelomic space*) that is lined by a ciliated epithelial layer called the *peritoneum*. The body wall is composed of living tissues (called the *endocyst*; Figure 1) below a non–living outer layer (called the *ectocyst*). In most branching and tubular colonies the ectocyst is chitinized and a variety of organic and inorganic particles adhere to it. That determinates the degree of attachment and also the mode of growth of the species. The ectocyst varies with age of the colony, being thin, flexible and transparent in young regions, and leathery, brittle or opaque in older regions. Non–tubular, gelatinous colonies may lack an ectocyst (e.g. *Cristatella, Lophopus*) or may secrete a massive jelly–like substance composed largely of water (e.g. *Pectinatella*; Wood and Okamura 2005).

Each zooid possesses a ciliated tentacular crown, called the *lophophore*, which surrounds the mouth and is used in feeding. In most phylactolaemates, the lophophore is U–shaped, with longer tentacles in an outer row and shorter tentacles in an inner row. In contrast, species of *Fredericella* possess a simple, circular lophophore, consisting of a single ring of tentacles. A prominent set of muscles allows retraction of the lophophore. The lophophores of freshwater bryozoans are quick to extend and in many species tend to remain extended even when directly probed with the tip of a needle (Wood and Okamura 2005).

The *digestive tract* of bryozoans is U–shaped, with the *anus* opening outside the perimeter of the lophophore. Bryozoans feed mainly on nanoplankton (flagellates, chlorophytes and some cyanobacteria). Mechanics of feeding reveals powerful feeding currents that are created by the ciliated tentacles of the lophophores. Small food particles are directed to the mouth along ciliated food grooves at the base of the lophophore tentacles. Larger food items may be flicked towards the mouth by individual tentacles, and the tentacles can also show concerted activity, in which the tentacle tips are brought together to enclose active food items such as protozoans and rotifers.

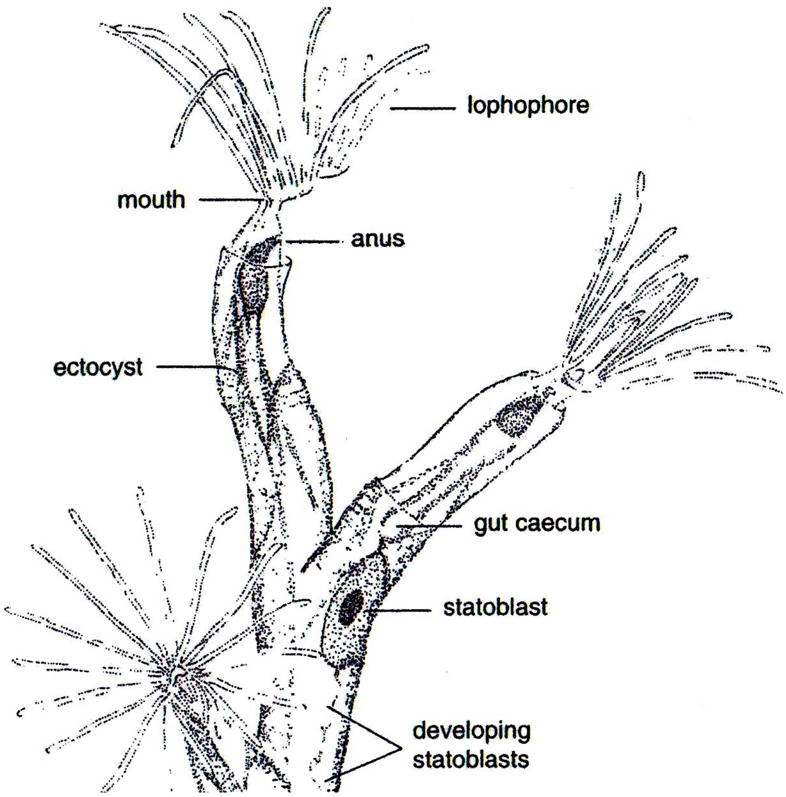

Figure 1. Zooids of *Plumatella emarginata*, showing major anatomical features (from Wood and Okamura 2005).

A strand of tissue, called the *funiculus*, extends from the gut (*caecum*) to an attachment on the body wall (Figure 2). The funiculus is the site of production of both sperm and dormant asexual stages called *statoblasts*. Young statoblasts appear as attached discs of white tissue developing within the body cavity, while older statoblasts are brown due to tanning of the chitin in the wall. Mature statoblasts detach from the funiculus and sometimes can be seen circulating freely in the body cavity (Wood and Okamura 2005).

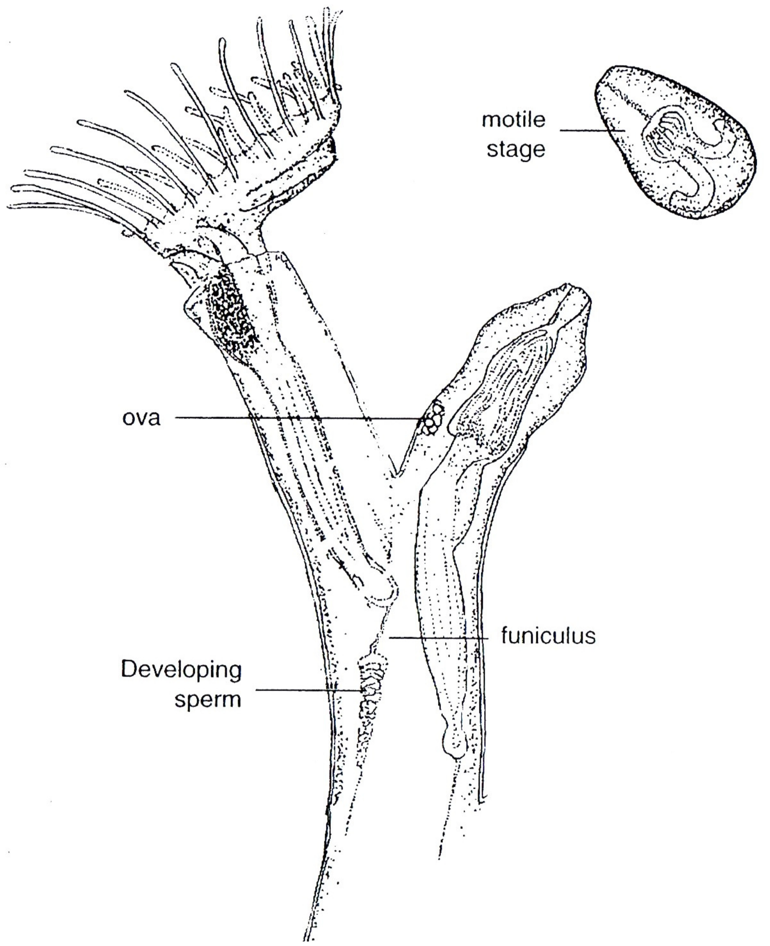

Figure 2. Sexual organs of a plumatellid bryozoan (from Wood and Okamura 2005).

The life cycle of bryozoans incorporates both asexual and sexual reproduction and including resting stages as dormant bodies.

Sexual reproduction typically occurs from early to mid summer and is generally fast. Sperm masses develop on the funiculus and later break away to circulate in the coelom. Clusters of ova develop on the peritoneum, embryos are brooded, and ciliated, larva–like motile stages are then released into the water column. There they swim only for a few hours before settling and metamorphosing into a small colony. The motile forms contain one to four zooids, depending on the species, which are surrounded by a ciliated mantle. The mantle unfolds at metamorphosis to expose a juvenile colony (Wood and Okamura 2005).

Asexual or clonal reproduction is the most important mode of reproduction in freshwater bryozoans, occurring throughout the growing season which is mostly between April and October in temperate zones. Asexual propagation can take place by the production of new zooids via budding, which first means an increase in colony size followed by colony fission in the case of gelatinous species, or by colony fragmentation in the case of chitinous forms. However, the most important mode of asexual propagation is the production of certain resting stages such as statoblasts and hibernaculae. Bryozoans usually undergo a dormant period in winter which means that their colonies completely disappear. In late spring or early summer, when favourable conditions establish, colonies can be found again. Zooids are able to hatch out from varoius kind of resting stages. In the case of the Phylactolaemates the valves of the statoblasts will separate and out of a single zooid a colony can be formed again by budding. Colony growth is always accompanied by the process of statoblast formation which will last throughout the year until environmental condition again worsen. Finally, in late autumn colonies degenerate and only the resting stages will remain, often for years, as they are protected by their heavily chitinsed layers.

There are several types of statoblasts produced by bryozoans:

- **Free statoblasts** (**floatoblasts**, Figure 3a) are released from colonies through the vestibular pore at the base of the lophophore. The chitinous valves are composed of two layers: the inner layer (*capsule*) encloses the germinal tissue and food reserves, and the outer layer (*periblast*) completely encloses the capsule. The periblast possesses a peripheral *annulus* and a central *fenestra*. The valves of most species are laterally asymmetric, with the so–called *ventral valve* having a larger fenestra and narrower annulus than the *dorsal valve*. Most of the floatoblasts have gas–filled chambers in the annulus that provide buoyancy and are dispersed by winds and currents. **Leptoblasts** are a special type of floatoblast (unique to *Plumatella casmiana*) which lacks the inner capsule and does not undergo a dormant phase. Instead, they contain a fully formed zooid enclosed only by a periblast. **Spinoblasts** (Figure 3b) are a type of floatoblasts with peripheral spines that occur in *Cristatella mucedo* and *Lophopus crystallinus*. They do not float unless first dried, suggesting an adaptation to drought conditions and spines may aid in the dispersal of the spinoblasts.

- **Sessile statoblasts** (**sessoblasts**, Figure 3c) are not released from colonies – they become cemented to the substratum. Like floatoblasts, these also have two chitinous valves, each composed of an outer periblast and an inner capsule. The *basal valve* is like an open pot cemented to the substratum, its sides forming a lateral *wall* which may bear tubercles or other features. The *frontal valve* forms a domed lid which is usually covered with a pattern of raised tubercles or intersecting net–like lines. The valves join at the periphery to form a thin, narrow annulus which projects outwards and is never inflated. The *suture* where the two valves join may be located anywhere between the base and the tip of the annulus.

- **Piptoblasts** (Figure 3d) are a third kind of statoblast produced only in the genus *Fredericella*. They are a bean–like structures, never released from the colony, but instead held tightly within the tubular branches, with tiny tooth–like processes that may help to hold the piptoblast onto the substratum (Wood and Okamura 2005).

Not all freshwater bryozoans produce statoblasts. In the Class *Gymnolaemata* a few species, such as *Paludicella*, isolate a small part of the colony, thicken the walls, and fill it with yolk and germinal tissue. This structure is called **hibernacula** and is capable of overwintering in a dormant state and then germinate whenever suitable conditions establish (Wood 2005a).

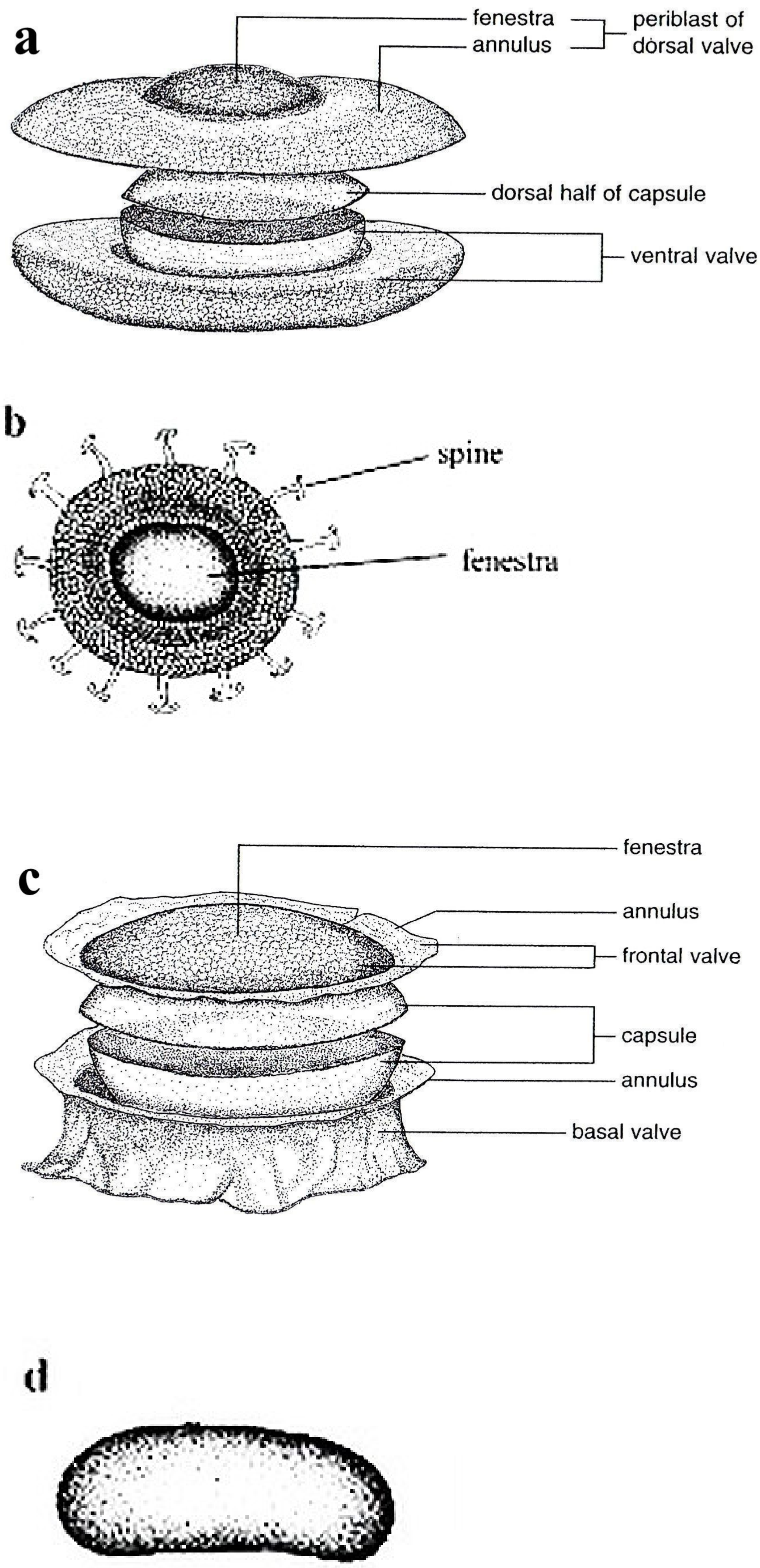

Figure 3. Morphological details of statoblasts: (a) floatoblast; (b) spinoblast; (c) sessoblast and (d) piptoblast (from Wood and Okamura 2005; www.answers.com).

1.2 Taxonomic characteristics of freshwater bryozoans

The Phylum Bryozoa is separated into three Classes (Ryland 2005):

- *Stenolaemata* (exclusively marine)
- *Gymnolaemata* (mostly marine)
- *Phylactolaemata* (freshwater).

Although both colony type and zooid morphology are used to classify bryozoans, zooidal characters are more reliable in marine bryozoans (Ryland 2005). In freshwater species, genera can often be determined from colony morphology alone, but identification to species level in the Class of *Phylactolaemata* almost always requires the presence of statoblasts (Wood 2005) and their close examination (Wood and Okamura 2005).

Examination of statoblasts includes:

- **Measurements of statoblasts** – the *overall length* is defined as the largest dimension of a valve, *overall width* is the largest dimension of a valve when measured at right angles to the first (length), *overall length of the fenestra* and *overall width of the fenestra* are the largest dimensions of fenestra. Measurements of sessile statoblasts should normally exclude the annulus, since the annulus is largely reduced and its orientation is variable.
- **Distinction between the fenestra and the capsule** – in most species the fresh floatoblast is inflated with a gas, making the annulus and fenestra clearly visible. However, this gas is often lost during prolonged storage and the chitinous annulus then becomes transparent, revealing the internal capsule and making the fenestra sometimes difficult to discern.
- **Examining free statoblasts in lateral view** – i.e. to make distinctions within the family of Plumatellidae. One way of holding a statoblast on edge is to support it on a thin shred of cotton wool in water placed in a shallow depression on a slide. A little manipulation using fine pins or forceps will place the statoblasts in any desired position.

- **Examining the surface texture –** it is usually necessary to separate the two statoblast valves which can be obtained by using potassium hydroxide solution and heat the sample over a small flame for about one minute (Wood and Okamura 2005).

The sites described below (Figure 4) refer to the ongoing study “First survey on freshwater bryozoans from Croatia“ (Wöss and Novosel). For a detailed description of the locations and sampling sites as well as coordinates see Garašić (2009).

Figure 4. Map of investigated locations in the Republic of Croatia in 2008 (Wöss and Novosel): 1 – Jarun; 2 – Crna Mlaka; 3 – Žumberak; 4 – Plitvice Lakes; 5 – Lonjsko Polje; 6 – Krka River.

1. JARUN

Jarun is situated in Zagreb, the capital city of Croatia. The whole area is the recreational and sports centre. It consists of two lakes - Veliko and Malo Jezero, canal, islands, beaches and lots of recreation terrains (Jarun webpage). Sampling took place in two sites: Otok ljubavi and Canal.

2. CRNA MLAKA

Crna Mlaka is a Special Ornithological Wildlife Sanctuary that is situated in the central part of swamps and forests of the River Kupa valley. The area of Crna Mlaka belongs to the accumulative-tectonic category of ground (terraced valleys, slips and swamp valleys). It is an active agriculture site (Crna Mlaka webpage). Four sites have been sampled: two ponds and two canals.

3. ŽUMBERAK

Žumberak is a part of the Žumberak–Samoborsko gorje Nature Park. It is a hilly area situated SW of Zagreb with height range from 180 – 1178 meters. Eastern part of the park is lower in height, consisting of Samoborska gora and many river valleys. There is no urban centres so it represents exclusively rural area (Žumberak–Samoborsko gorje webpage). Five sites have been sampled: Rajska Lakes, Divlje vode, Marinići Fishfarm, Dane–Kordići Pond and Budinjak Pond.

4. PLITVICE LAKES

National Park Plitvice Lakes are located in part of Croatia where there is a transition from northern flat land towards a bit more elevated karsted mountain area. The sixteen lakes are separated into an upper and lower cluster formed by runoff from the mountains. The lakes collectively cover an area of about two square kilometers, with the water exiting from the lowest lake and forming Korana River. The Plitvice Lakes lie in a basin of karstic rock, mainly dolomitic limestone. They are separated by natural dams of travertine, which is deposited by the action of moss, algae and bacteria. The encrusted plants and bacteria accumulate on top of each other, forming travertine barriers which grow at the rate of about 1 centimeter per year (Wikipedia webpage). Nine sites have been sampled: Kozjak Bridge, Rječica Stream, Prošćansko Lake, Matica River, Black River, White River, Batinovac Lake, Okrugljak Lake and a pond near Galovac Lake.

5. LONJSKO POLJE

Lonjsko Polje is the largest protected swamp area in Croatia and it is included in the Ramsar List of Wetlands of International Importance especially as Waterfowl Habitat and in the Important Bird Areas (IBA). It encompasses three fields (Lonjsko, Mokro and Poganovo Polje) which can be flooded by Sava, Una, Kupa, Lonja and Strug River (Lonjsko Polje webpage). Five sites have been sampled: Krapje đol, Puska rukavac, Mrtvaaja Mužilovčica, Mužilovčica and Čigoč.

6. KRKA RIVER

The Krka National Park is located in central Dalmatia and encompasses an area of 109 square kilometers along the Krka River with a source at the base of the Dinaric Mountains. The lenght of the freshwater section of the river is 49 kilometers and that of the brackish section is 23.5 kilometers. The Krka River lies on limestone deposits and form travertin barriers which create waterfalls. It is a natural and carstic phenomenon (Krka River webpage). Twenty five sites along the Krka River were sampled during this survey.

3.1 Sampling

The presence of phylactolaemate colonies usually can be detected by the presence of floatoblasts in the water (Wood and Okamura 2005). In case of colonies, they have to be kept intact (they have to be removed along with the substratum on which they occur). Basic tools for collecting bryozoans are: 10x or 14x magnifying lens (or loup), fixed blade knife (it has to be sharp) and wide–mouth polyethylene jar (Wood 2005) or canister (Figure 5).

Colony sampling includes investigating natural substrates (submerged logs, branches, aquatic plants and rocks) by wading along the shore. Small pruning–shears are used for cutting the smaller branches or twigs of wooden substrates and aquatic plants, while a handsaw is used for thicker branches. In case of massive logs, where no parts can be removed out of the water, the colonies are scraped carefully from the substrate with a knife (Wöss 2004).

Figure 5. Basic tools for collecting bryozoans (from Wood 2005).

3.2 Species identification

Colonies are roughly identified *in situ* (with magnifying lens) and transported into the laboratory for further investigation.

In the laboratory, a stereomicroscope is used to inspect the samples collected in the field. Before the examination, all dry samples are put in the water for about half an hour so that statoblasts and colonies can be isolated. The samples are taken out from the jars and put in a Petri dish for further investigation.

Statoblasts are isolated under the stereomicroscope by needles electrolytically sharpened to create special thin points. This allows easier extraction of the resting stages out of the colony tubes and enables further dissections of the statoblasts.

Isolated resting stages have been stored in Eppendorf tubes filled with ethyl alcohol (the range of 70% to 96%) before using them for scanning electron microscopy (SEM) investigation.

Scanning electron microscopy (SEM) is broadly used to study bryozoan skeletons and has became the standard tool in taxonomic work (Walzl and Wöss 2005). It is particularly suitable for statoblasts since they possess chitinised cuticula. SEM pictures of the resting stages were made at the Natural History Museum in London in a *LEO 1455* variable pressure scanning electron microscope by Emmy Wöss.

For species identification following keys have been used: Lacourt 1968 and Wood and Okamura 2005.

4.1 Species list

The species list of freshwater bryozoans in Croatia is based on preliminary results of the first survey on freshwater bryozoans from Croatia (Wöss and Novosel). So far, eleven freshwater bryozoan species were identified on the territory of the Republic of Croatia, including ten phylactolaemates and one gymnolaemate.

Table 1. A list of determined species (preliminary results, Wöss and Novosel, *in prep.*)

Class Gymnolaemata, Subclass Ctenostomata

Family Paludicellidae
1. *Paludicella articulata* (Ehrenberg, 1831)

Class Phylactolaemata

Family Fredericellidae
2. *Fredericella sultana* Blumenbach, 1779
Family Plumatellidae
3. *Hyalinella punctata* (Hancock, 1850)
4. *Plumatella casmiana* Oka, 1907
5. *Plumatella emarginata* Allman, 1844
6. *Plumatella fruticosa* Allman, 1844
7. *Plumatella fungosa* (Pallas, 1768)
8. *Plumatella repens* (Linnaeus, 1758)
9. *Plumatella geimermassardi* Wood & Okamura, 2004
Family Cristatellidae
10. *Cristatella mucedo* Cuvier, 1798
Family Lophopodidae
11. *Lophopus crystallinus* (Pallas, 1768)

4.2 Description of species

Class Gymnolaemata

Subclass Ctenostomata

Family Paludicellidae

Genus *Paludicella*

***Paludicella articulata* (Ehrenberg, 1831)**

Description. Colonies form shiny threads across the substratum, each composed of a linear series of slender, spindle–shaped zooids (Figure 6). The body wall is transparent, colourless, and somewhat rigid. Each zooid can send out lateral buds on opposite sides, almost at right angles to the main axis. Incomplete septa occur between all zooids. The lophophore is circular, carrying usually less tentacles than any *Phylactolaemata* (14–23). In contrast to *Phylactolaemata* species which have terminal positon where the lophophore projects, species of *Gymnolaemata* have subterminal position of the orifice (Figure 7). When the lophophore is fully retracted, muscles pull the orifice into a quadrangular shape (Wood and Okamura 2005).

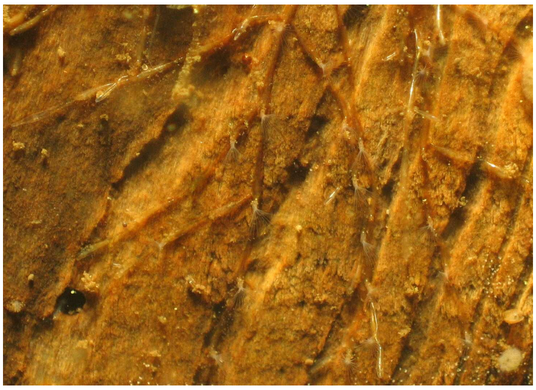

Figure 6. *Paludicella articulata*: colony on a substrate (from www.bryozoans.nl).

Figure 7. *Paludicella articulata*: a zooid with circular lophophore (from www.bryozoans.nl).

Distribution. *Paludicella articulata* is known worldwide, even occurring in flowing or turbulent water (Wood and Okamura 2005).

Biology. *Paludicella articulata* produces hibernaculae instead of statoblasts as resting stage in asexual reproduction (Figure 8). Colonies of *P. articulata* germinate from their overwintering stages in late April, and after a few mostly asexual cycles they disappear by about mid–November. This species lacks floating resting stage so its colonising ability is poor. *P. articulata* can be found in water deeper than 60cm (Wöss 1996).

Figure 8. *Paludicella articulata*: hibernacula
(from www.bryozoans.nl).

Identification. Despite its circular arrangement of tentacles, the slender zooids and clear, stiff body wall of *P. articulata* set it apart from fredericellid bryozoans. The absence of stolon–like parts and relatively large number of tentacles distinguish it from *Victorella* (Wood and Okamura 2005).

Class Phylactolaemata

Family Fredericellidae

Order Plumatellida

Genus *Fredericella*

Fredericella sultana **Blumenbach, 1779**

Description. Colonies are free or adherent, recumbent or erect, with dichotomous and usually open branching of the tubes; the cuticula is dark brown, usually with coarse incrustation (Figure 9 and 10). The polypides are few in number, with 19 to 24 short, fragile tentacles (Lacourt 1968). The statoblasts of *F. sultana*, which does not produce floatoblasts, are piptoblasts (Figure 11). They do not produce an adhesive secretion and generally are released from the parent colony when the zooid walls degenerate. The surface of the piptoblast capsule is smooth, and the annulus, if present at all, is incomplete. The capsule suture may be visible at the edge (Mundy 1980). The piptoblast shape is oblong, oval or kidney–shaped, with rounded ends (Wood and Okamura 2005).

Figure 9. *Fredericella sultana*: colony (from www.bryozoans.nl).

Figure 10. Circular lophophore of *Fredericella sultana* (from www.bryozoans.nl).

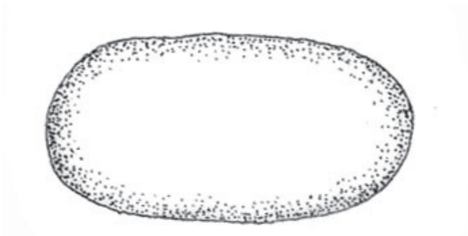

Figure 11. Piptoblast of *Fredericella sultana* (from www.answers.com).

Distribution. *Fredericella sultana* is the most common fredericellid in Britain, Ireland and Europe, also occuring in Asia, Australia and New Zeland, but only rarely in North America (Wood and Okamura 2005).

Biology. The species occurs in a wide range of environments, but seems to thrive in habitats of low productivity, especially in flowing or lightly turbulent water (Wood and Okamura 2005). It can also occur in brackish water, but then is less developed (Lacourt 1968). Piptoblasts may be regarded as the most primitive type of statoblasts, from which both the sessoblast and the floatoblast have evolved. *F. sultana*, since it is erect species, can grow above the others and co–occur with plumatellid and hyaline forms, but it has a poor colonising ability (Wöss 1996).

Identification. Like *Fredericella sultana*, several other species of freshwater bryozoans have slender branching tubules that become upright and free from the substratum. They can be distinguished by their lophophores and statoblasts (Wood and Okamura 2005).

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Plumatella*

***Plumatella casmiana* Oka, 1907**

Description. The colony is normally compact, with short, richly branched tubules, usually bearing a conspicuous raphe. Zooids adhere to the substratum througout their length, but severely crowded they may grow perpendicular to the substratum as parallel tubules fused together (Figure 12). The colony wall ranges from semi–transparent to opaque, except for a distinct transparent area that surrounds the zooid tip and continues as a thin line along the raphe. The lophophore is relatively small (Wood and Okamura 2005), bearing only 25–40 tentacles (Walzl and Wöss 2005; Figure 13). Two types of free statoblasts are produced in *Plumatella casmiana*. A „capsuled“ floatoblast has the typical plumatellid structure and function, with a well developed periblast enclosing the capsule. The second type is called a „leptoblast“ (Figure 14); it lacks an internal capsule and instead encloses a fully developed zooid within a membranous periblast. With a very narrow annulus, a leptoblast is only weakly buoyant and germinates immediately upon release from the colony. Unlike other statoblasts, the valves of a leptoblast are never completely fused together. The sessile statoblast is distinctive for its weak tuberculation on the frontal valve and the unusually narrow annulus (Wood and Okamura 2005).

Figure 12. Colony of *Plumatella casmiana* (photo Emmy Wöss).

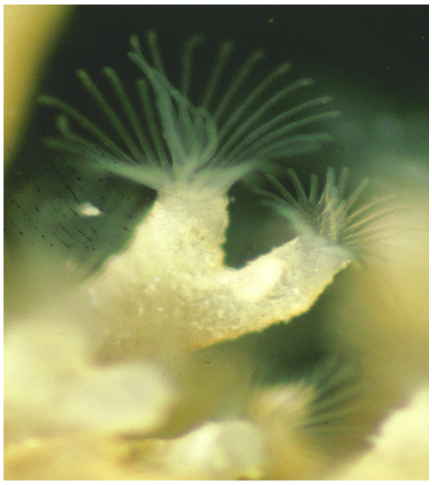

Figure 13. Lophophore of *Plumatella casmiana* (photo Emmy Wöss).

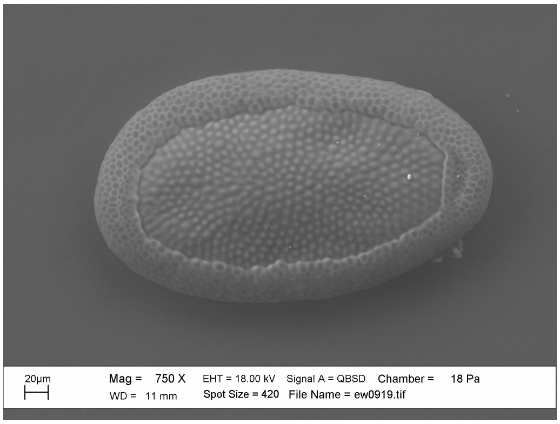

Figure 14. SEM micrograph of *P. casmiana* leptoblast (photo Emmy Wöss).

Distribution. *Plumatella casmiana* now is consider to be a cosmopolitan species, although it has not been found in Australia and South America (Massard and Geimer 2008).

Biology. Lacourt (1968) described that the main substrates for the species are water plants, but it is also found on stones and shells of freshwater snails. Wöss (1996) mentions that in an experimental study on bryozoan growth on artificial substrates *P. casmiana* is the best competitor among several plumatellids, presumably due to its rapid asexual reproduction by leptoblasts, as well as it showes good colonising ability due to its great variety of propagation strategies.

Identification. The flat, compact and branching colony and a frontal raphe along the tubules, are sometimes sufficient for a tentative identification. However, the colony may look different, depending on the degree of crowding, growth rate, water current, and probably other factors. Fortunately, the statoblasts of *P. casmiana* are highly distinctive, especially the unique leptoblast. The small lophophore is also quite characteristic: no other European plumatellid has so few tentacles (Wood and Okamura 2005).

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Plumatella*

***Plumatella emarginata* Allman, 1844**

Description. The colony appearance is highly variable. Zooids may be dense and compact, or very loosely arranged with branches dangling free from the substratum (Figure 15). A grey pigment often appears on the body wall of even young zooids. A contrasting transparent region encircles the zooid tip and tapers away on the frontal surface of the zooid to form a V-shaped „neckline“ (Figure 16). This feature gives the species name „emarginata“, and although it also appears in several other plumatellids, it is seldom as pronounced as it is in this species. The tip of the V–shaped emargination marks the beginning of a modest raphe, which extends along the frontal (dorsal) side that is not adjacent to the substratum. The raphe is absent on free branches. Dark septa are common in this species, usually positioned at right angles to the main branch axis (Wood and Okamura 2005). The number of tentacles is 30 to 54 (Lacourt 1968). The floatoblasts (Figure 17) are usually numerous, forming strings (Lacourt 1968), and are distinguished by the relatively small dorsal fenestra and the very pronounced lateral asymmetry (Wood and Okamura 2005). Their shape is oval, the capsule is almost round; the annulus is three times wider at the poles than laterally (Lacourt 1968). The dorsal valve is almost flat, whereas the ventral valve is strongly convex. Moreover, the ventral valve is slightly larger than the dorsal valve, its margins extending beyond the edge of the dorsal valve on all sides so that the entire suture is visible from a dorsal view. The ventral fenestra is smooth and the dorsal fenestra is distinctly tuberculated (Wood and Okamura 2005). This species also has sessoblasts which are oval with small tubercles covering the dorsal surface and the lateral walls. The annulus projects at an angle of about 45° to the horizontal plane of the sessoblast, and has a slightly undulating surface. The base of the lateral walls is thickened, obscuring the adhesive layer beneath the sessoblast (Mundy 1980).

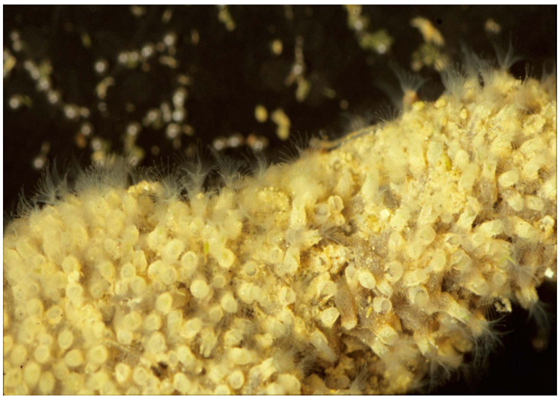

Figure 15. *Plumatella emarginata*: colony (photo Emmy Wöss).

Figure 16. Zooids of *Plumatella emarginata* (photo Emmy Wöss).

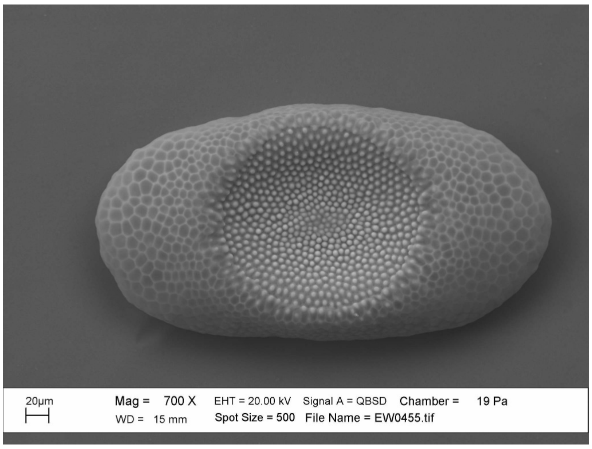

Figure 17. SEM micrograph of *P. emarginata* floatoblast ventral view (photo Emmy Wöss).

Distribution. *Plumatella emarginata* is common throughout Britain, Ireland and the continent of Europe, also in North America and New Zeland (Wood and Okamura 2005).

Biology. *Plumatella emarginata* occurs in a wide variety of habitats, but it is particularly tolerant of rapidly–flowing water, where it may form a thick, uneven blanket over the substratum (Wood and Okamura 2005). This species is frequently found on Gastropod shells (e.g. *Paludina sp.*), and on those of Lamellibranchs such as *Unio* and *Anodonta*. Some authors see this as a symbiosis between the Bryozoa and the Molluscs; the current created by the Molluscs in taking up food also carries food to the Bryozoa (Lacourt 1968).

Identification. *Plumatella emarginata* can be easily mistaken for other species. In its diffuse, stringly form it can look like *Fredericella* or even like *Plumatella fruticosa*. Compact colonies may resemble *Plumatella casmiana*, and the floatoblast is easily confused with that of *Plumatella reticulata*. To distinguish species it is important to look for the following characteristic features (Wood and Okamura 2005):

1. Floatoblasts of *P. emarginata* are laterally asymmetrical, with a small dorsal fenestra. This alone is sufficient for identification of this species. To further confirm that the specimen is not *P. reticulata*, check that the sessile statoblast is tuberculated, not reticulated, across the frontal valve.

2. If statoblasts are not available, look for the clear emargination around the tip of the zooid, a raphe along the zooid, and the presence of perpendicular septa.

3. If the colony has many long, free branches, note that either a horseshoe–shaped lophophore or a sessile statoblast will distinguish *P. emarginata* from fredericellids.

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Plumatella*

***Plumatella fruticosa* Allman, 1844**

Description. Colonies are diffuse, with long, narrow branches and widely spaced zooids (Figure 18). Many branches tend to grow anter–like, free from the substratum. A raphe is often apparent on adherent portions. Free side branches often detach from the main stem, leaving behind a distinctive series of stumps (Wood and Okamura 2005). The cuticula is dark reddish–brown, transparent, stiff, brittle, and sometimes incrusted. The polypides carry 30–50 tentacles (Figure 19). The floatoblasts are elongate to spindle–shaped and numerous; the annulus is very wide at the poles, where it is six to nine times wider than laterally; laterally, the annulus is very narrow (Figure 20). The network of the chambers is extremely distinct

(Lacourt 1968) with three to eight pores per chamber, arranged in a ring near the centre of each chamber (Mundy 1980). The sessoblasts of *P. fruticosa* are rarely found, and occur only in the older parts of mature colonies. They have a distinctive long–oval outline, the dorsal surface being covered, except towards the centre, with irregular ridges and tubercles. This patterning extends to the annulus, where it is more regularly reticulated. The presence of this pattern of ridges at the edge of the annulus accounts for the „regularly dentate“ appearance of the outer margin (Mundy 1980).

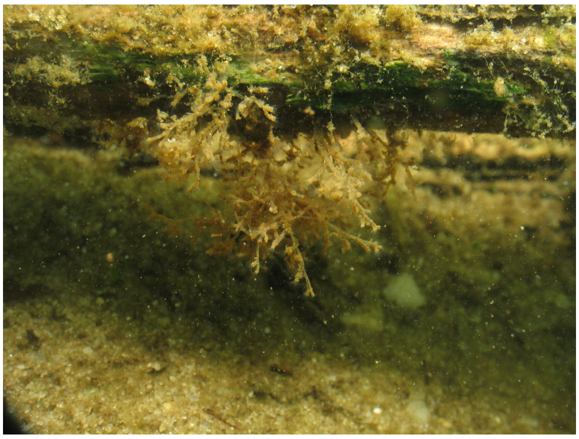

Figure 18. *Plumatella fruticosa*: colony (from www. bryozoans.nl).

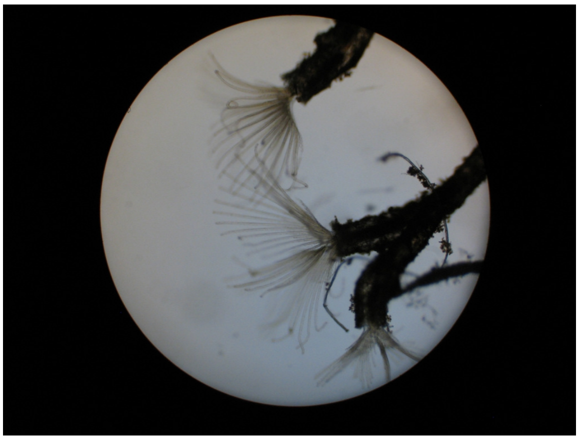

Figure 19. *Plumatella fruticosa*: zooids (from www. bryozoans.nl).

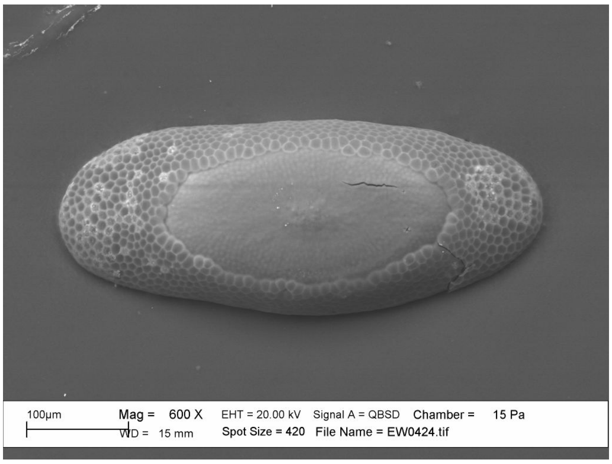

Figure 20. SEM micrograph of *P. fruticosa* floatoblast ventral view (photo Emmy Wöss).

Distribution. *Plumatella fruticosa* is evidently restricted to the holarctic region, but has not yet been found in North Africa. Little is known about its occurence in Asia, where the species has been found with certainty only in Japan (Lacourt 1968).

Biology. Colonies usually occur in cool waters of low productivity, often in association with *Fredericella* species, which they strongly resemble (Wood and Okamura 2005). The bathymetric occurrence of the species ranges from the surface to a depth of several metres. *P. fruticosa* is a rather rare species, which as a rule is also not numerous locally (Lacourt 1968).

Identification. Among the plumatellids, *P. fruticosa* has the most fine, long branches, and these are often unattached to the substratum. The long, narrow proportions of the statoblast are unlike any others in the region. The horseshoe–shaped lophophore and the typical plumatellid statoblasts distinguish it from fredericellid species (Wood and Okamura 2005).

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Plumatella*

***Plumatella fungosa* (Pallas, 1768)**

Description. Small colonies of branching tubules normally grow close to the substratum, although free branches are not uncommon. Crowded zooids tend to fuse in straight, parallel lines, forming a solid, greyish structure that reaches a thickness of 4 cm or more (Figure 21). Such colonies are capable of rapid growth in highly productive habitats. Tubules are generally transparent, the chitinous outer portion becoming yellowish, amber, or dark brown with age (Figure 22). Dark internal septa are frequent (Wood and Okamura 2005). The zooid has 40–60 tentacles (Walzl and Wöss 2005). The floatoblasts (Figure 23) are broadly oval (Lacourt 1968), normally self–inflated and buoyant, but may fail to inflate during rapid growth. They are often produced in large numbers and many are retained within the colony. The dorsal fenestra is round and relatively small; the ventral fenestra is much larger and oval, often with a central prominence. The dorsal valve is much flatter than the ventral valve, producing a distinct lateral asymmetry (Wood and Okamura 2005). Scanning electron microscopy reveales tubercles of uniform size on both of the fenestra and the annulus. The size of tubercles varies greatly among colonies, and a reticulation may or may not be apparent. The suture between the dorsal and ventral valves is a prominent ridge–like cord with lateral ribs (Wood and Okamura 2005). Sessile statoblasts of *P. fungosa* have a well developed annulus, sometimes with faint tubercles. The frontal valve is completely covered with small tubercles, and tubercles also appear on the lateral wall (Wood and Okamura 2005).

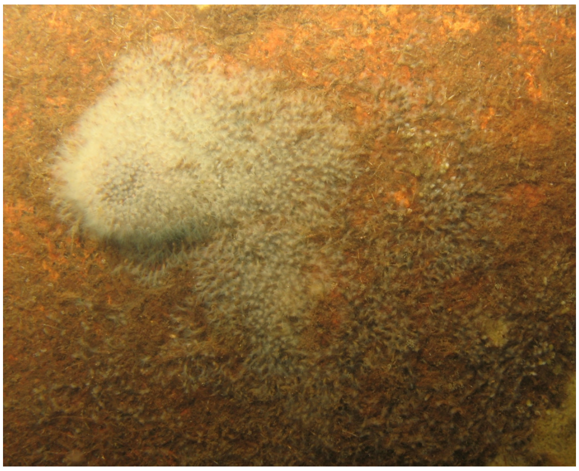

Figure 21. *Plumatella fungosa* colony on a substrate (from www.bryozoans.nl).

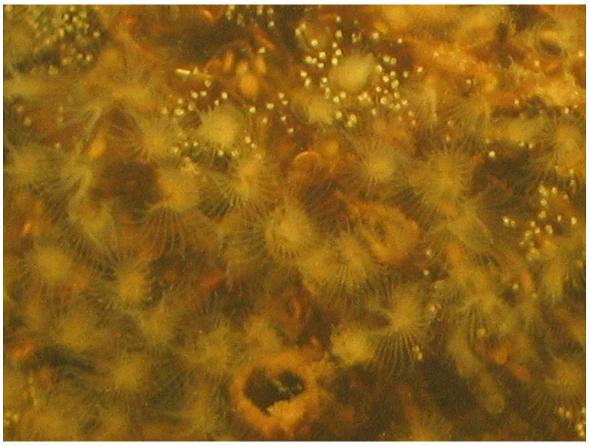

Figure 22. Zooids of *Plumatella fungosa* (from www.bryozoans.nl).

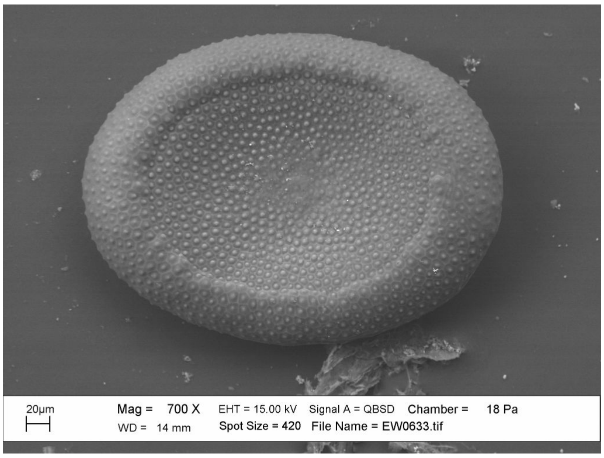

Figure 23. SEM micrograph of *P. fungosa* floatoblast ventral view (photo Emmy Wöss).

Distribution. The species is common and widely distributed throughout Britain, Ireland and Europe (Wood and Okamura 2005).

Biology. *Plumatella fungosa* flourishes in warm, eutrophic waters, and it is among the most tolerant of all freshwater bryozoans to organic polution (Wood and Okamura 2005). This species avoids the superficial water layers and reaches a depth of several metres. It is found exclusively on sturdy, firmly–embedded, or compact substrates, often also on shells of Gastropods and fresh–water mussels, never on green parts of plants (Lacourt 1968). In Austria, this species is the dominant bryozoan in water bodies of riverine forests with highly fluctuable water level. Furthermore, it is a species characterized with high investment in sexual reproduction. Nevertheless, it showed poor competitive ability (Wöss 1996).

Identification. The large chunky, darkish colonies make *Plumatella fungosa* one of the most recognizable freshwater bryozoan species in Europe. However, smaller colonies of *P. fungosa* cannot be reliably distinguished from those of *Plumatella repens* or *P. rugosa* (Wood and Okamura 2005). SEM investigation of the floatoblast is therefore essential for correct identification.

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Plumatella*

***Plumatella geimermassardi* Wood & Okamura, 2004**

Description. Colonies are formed as branching tubules of uniform diameter, the branches initially attached fully to the substrate and spreading widely on unrestricted surfaces (Figure 24); zooids becoming crowded on limited substrate with occasional free branching, branches sometimes fusing (Wood and Okamura 2004) to produce thick, ropy masses. The colony wall is smooth and glassy, seldom encrusted, nearly colourless in young colonies, becoming darker with age. Usually there is no raphe. Internal septa (Figure 25) range from infrequent to abundant (Wood and Okamura 2005). The number of tentacles is around 30–40 (Wood and Okamura 2004). Floatoblasts (Figure 26) are broadly oval with a relatively large dorsal fenestra. Lateral symmetry is variable: valves may be equally convex, or the dorsal valve may be almost flat. Polar grooves range from small and shallow to long, deep and narrow. Tubercles on the dorsal and ventral fenestrae range from low and indistinct to sharply defined, especially near the periphery where they spill onto the annulus. Reticulation is faint or absent. Scanning electron microscopy of the floatoblast of *P. geimermassardi* shows an annulus with tubercles that are extremely low, rounded, and often fused to give an oddly lumpy appearance. Sessile statoblast frontal valves of *P. geimermassardi* are covered with uniform tubercles which may spill onto the annulus. In some cases the tubercles on the annulus coalesce into elongated, radiating ridges which give the annulus a fluted appearance. The lateral wall is seldom well developed, so the annulus lies very close to the substratum (Wood and Okamura 2005).

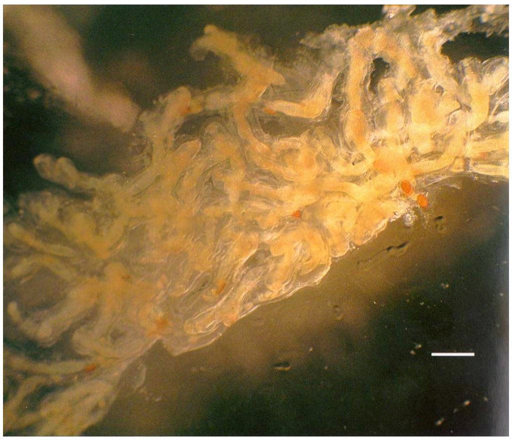

Figure 24. *Plumatella geimermassardi*. Portion of a whitish colony. Scale bar 1 mm (from Taticchi, Pieroni, Gustinelli and Prearo 2005).

Figure 25. *Plumatella geimermassardi*. Older tubules with evident septa (arrow). Scale bar 0.5 mm (from Taticchi, Pieroni, Gustinelli and Prearo 2005).

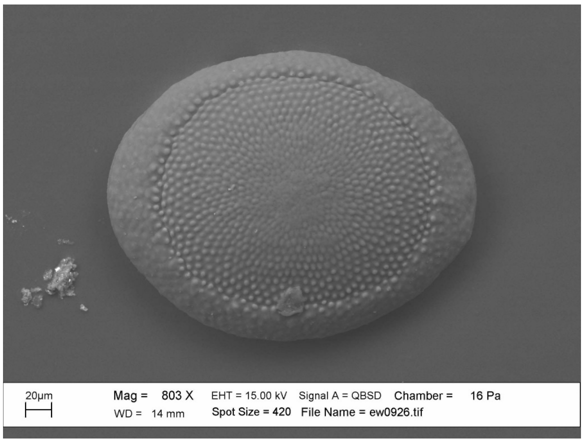

Figure 26. SEM micrograph of *P. geimermassardi* floatoblast ventral view (photo Emmy Wöss).

Distribution. *Plumatella geimermassardi* has been reported from Britain, Ireland, Germany, Italy, and Finland. It is probably widely distributed throughout much of the Europe.

Biology. *P. geimermassardi* is a relatively newly recognized and described species. So far, it was found in lentic water bodies, such as lakes and ponds.

Identification. The floatoblast of *P. geimermassardi* is unique with its relatively small size, large dorsal fenestra and uniformly narrow ventral annulus. The sessile statoblast lies unusually close to the substratum (Wood and Okamura 2005).

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Plumatella*

***Plumatella repens* (Linnaeus, 1758)**

Description. The colony is adherent and consists of long tubes growing radially and repeatedly branched in an open manner (Figure 27), but sometimes very compact with erect tubes (Lacourt 1968). There is never a raphe along the tubules. The colony wall is often colourless and transparent, but also brownish, with little encrustration. Septa are rare. Under crowded conditions tubules may be in close contact, but they never fuse. The polypides carry 40–60 tentacles (Figure 28). In the floatoblasts (Figure 29), the length of the dorsal fenestra is more than half the total lenght of the statoblast. In lateral view the valves are almost equally convex, bulging on both sides. The dorsal valve has large tubercles along the periphery of the fenestra, becoming much smaller and interstitial towards the fenestra’s centre. Scanning electron microscopy shows no tubercles on the annulus, but usually there are very small, rash–like bumps, termed *nodules*, of variable density. The suture between the two valves is a single cord with a row of low tubercles on either side, the complex somewhat resembling a zipper (Wood and Okamura 2005). The sessile statoblasts are large and rounded oval (Lacourt 1968), the annulus is wide and reticulated. Large, crowded tubercles cover the frontal valve, and interstitial tubercules appear on the lateral wall (Wood and Okamura 2005).

Figure 27. *Plumatella repens* on water lily leaf.

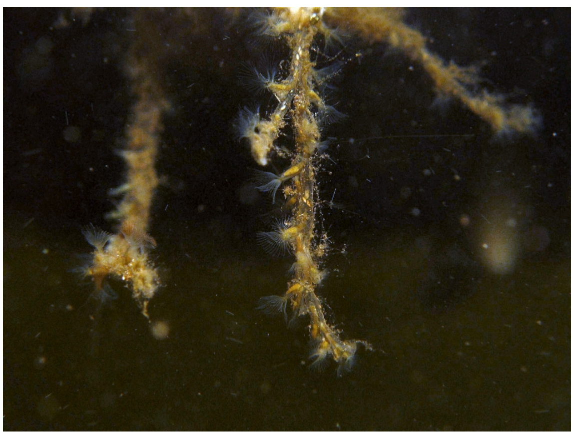

Figure 28. *Plumatella repens* zooids (from www.bryozoans.nl).

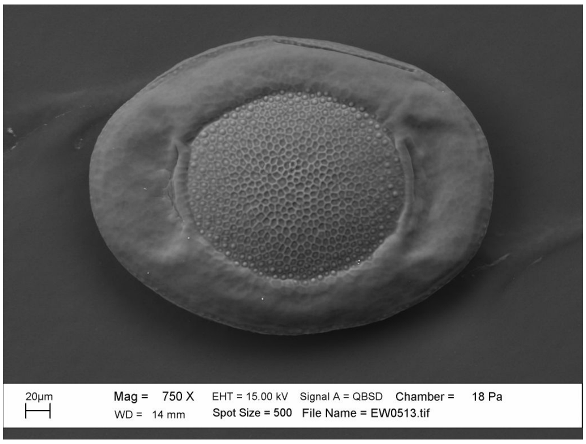

Figure 29. SEM micrograph of *P. repens* floatoblast dorsal view (photo Emmy Wöss).

Distribution. *P. repens* was considered to be a cosmopolitan species for a long time, but now that statement is under consideration. Former records of *P. repens* may include new species (Massard and Geimer 2008).

Biology. *P. repens* is common almost everywhere and it is even found in brackish water. Lacourt (1968) stated that its bathymetric distribution is usually limited to the upper water layers.

Identification. *Plumatella repens* is easily confused with small colonies of *P. fungosa*. Both are common and can occur in similar habitats. SEM investigation of floatoblasts is essential for identification.

Class Phylactolaemata

Family Plumatellidae

Order Plumatellida

Genus *Hyalinella*

***Hyalinella punctata* (Hancock, 1850)**

Description. Colonies are composed of sparsely branching tubules attached to the substratum throughout their entire length (Figure 30). The colony wall is thick, transparent, and lacking any of the sclerotised outer cuticle typically seen in other tubular species. It often bears uniformly distributed, small white dots of unknown function, most easily visible near the zooid tip (Figure 31). Rapid colony growth of *H. punctata* can lead to the formation of a dense sheet of zooids across the substratum. There is no trace of a raphe. When growing alongside any other tubular species it is immediately obvious that colony branches of *H. punctata* are somewhat larger in diameter. Individual zooids with extended lophophores normally protrude only slightly from the main branch, but may extend further in a near vertical position when crowded on all sides by other zooids. In a retracted state the orifice is nearly in line with the colony surface. Floatoblasts (Figure 32) are the largest of any European plumatellid. Since the annular chambers are never self–inflated, the fresh statoblast appears uniformly dark, almost black, with little distinction between annulus and fenestra. Upon desiccation, however, the annular cells become filled with air and take on the light, reflective tone of a typical plumatellid floatoblast. There are no sessile statoblasts (Wood and Okamura 2005).

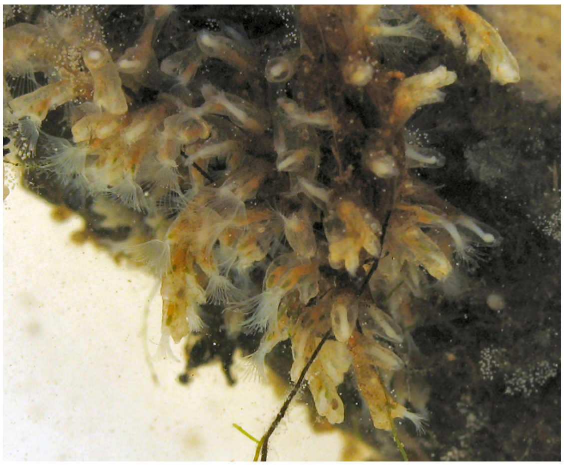

Figure 30. *Hyalinella punctata*: colony (from www.bryozoans.nl).

Figure 31. Zooid of *Hyalinella punctata* (from www.bryozoans.nl).

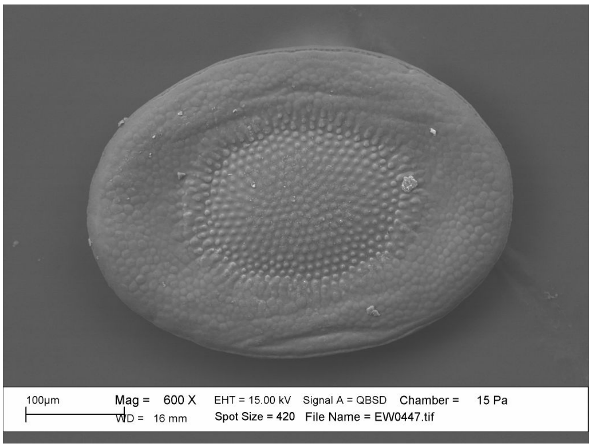

Figure 32. SEM micrograph of *H. punctata* floatoblast dorsal view (photo Emmy Wöss).

Distribution. *Hyalinella punctata* has been widely reported worldwide, but verified specimens are known only from Britain and Ireland in Europe, North America and northern Asia (Wood and Okamura 2005).

Biology. The substrate consists of leaves and stems of water plants, branches, bark, wood and stones. The bathymetric distribution extends from about 25 cm to a few metres mostly. It lives in water with temperature ranging from 18 to 25°C and has also been found in brackish water (Lacourt 1968). Since *H. punctata* has only floatoblasts, they possess a kind of double function: before drying out, they are unable to float and function similar to a sessoblast; once dry, they start to float. Colonies of *Hyalinella punctata* have an extraordinarily rapid growth rate and therefore have good colonising and competitive ability (Wöss 1996).

Identification. *Hyalinella punctata* is one of the few plumatellids that can be positively identified without statoblasts. The wide tubules, thick and transparent body wall, sparse branching and weakly protruded zooids are distinctive. However, the presence of large, dark, floatoblasts will confirm the identification (Wood and Okamura 2005).

Class Phylactolaemata

Order Plumatellida

Family Lophopodidae

Genus *Lophopus*

***Lophopus crystallinus* (Pallas 1768)**

Description. The colony is sac–shaped (Figure 33) in the young stage, gradually becoming lobulate and reaching a size of about 40 mm; there are no septa; the cuticula is soft and completely transparent without incrustration, as lying loose on the ectocyst (Lacourt 1968). Colonies are small (2–40 zooids, each with 60 tentacles; Figure 34) and irregular in shape, often attached to other colonies by tough, mucus–like strings. Budding is in a frontal–lateral direction, producing advancing rows of zooids more numerous than the generation behind them and resulting, roughly, in a fan–shaped colony. Developing buds protrude as rounded knobs. Colonies adhere only weakly to the substratum and are capable of thriving in soft sediments (Wood and Okamura 2005). They produce only one form of statoblasts, the floatoblasts (Figure 35), which are large, elongate and pointed at the poles. The annulus is wide and grayish–brown; the capsule is brown and nearly round (Lacourt 1968).

Figure 33. Sac-shaped colony of *Lophopus crystallinus* (from www.bryozoans.nl).

Figure 34. *Lophopus crystallinus* lophophore (from www.bryozoans. nl).

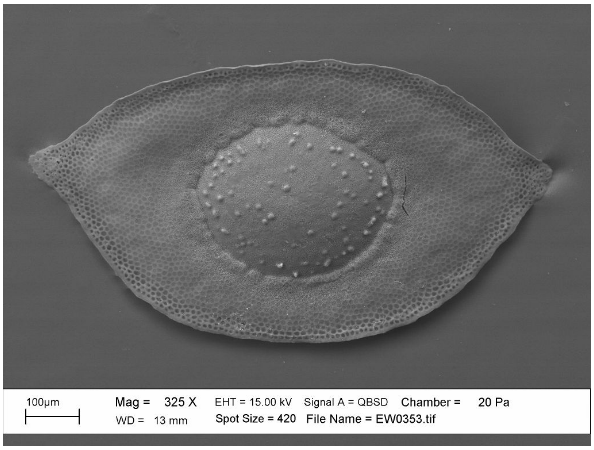

Figure 35. SEM micrograph of *L. crystallinus* floatoblast ventral view (photo Emmy Wöss).

Distribution. *Lophopus crystallinus* occurs throughout Europe, but is generally considered to be extremely rare (Wood and Okamura 2005).

Biology. The substrate they are found on, are often water plants. The bathymetric distribution reaches from just under the surface to a depth of about 2 m (Lacourt 1968). Its ecology is poorly known. It is the only bryozoan included as a priority species in the Biodiversity Action

Plan which aims to conserve biodiversity within the UK, and it is the only phylactolaemate in the Red Data Book (Wood and Okamura 2005).

Identification. Colonies lacking statoblasts may superficially resemble *Lophopodella carteri* or small colonies of *Cristatella mucedo*. However, *Lophopus crystallinus* does not have the compact, globular shape of *Lophopodella*, nor the linear symmetry of *Cristatella*.

Class Phylactolaemata

Family Cristatellidae

Order Plumatellida

Genus *Cristatella*

***Cristatella mucedo* Cuvier, 1798**

Description. The colony is elongated and worm–shaped (Figure 36), it lacks branching and lobes (Lacourt 1968). Colonies are composed of zooids crowded together in masses that are 4-5 mm wide and up to 80 mm long. The body wall is thick, transparent and colourless. As in most non–tubular species, the U–shaped lophophore is bearing more than 70 tentacles (Figure 37). In their feeding position, zooids are greatly extended, giving the undisturbed a “fuzzy”, caterpillar–like appearance. Colonies are capable of gliding slowly along the substratum. They actively divide by fission. The spinoblast is discoidal (Figure 38). Wiry spines with terminal hooks originate mostly from the dorsal fenestra, and radiate outward beyond the margin of the annulus. The suture joining the dorsal and ventral valves is not peripheral but it is instead concealed around the outer edge of the ventral fenestra. The annulus is self–inflating and the statoblast is buoyant upon release (Wood and Okamura 2005).

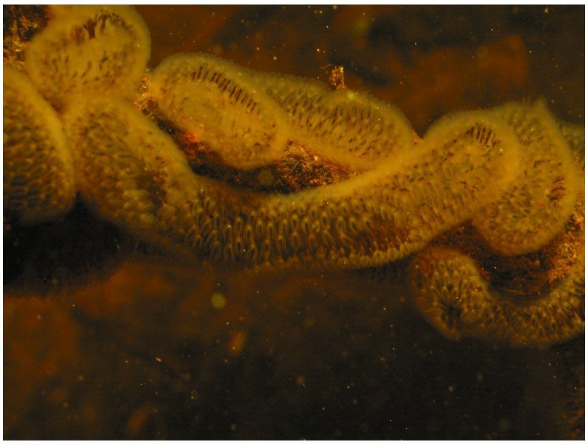

Figure 36. Worm-shaped colony of *Cristatella mucedo* (from www.bryozoans.nl).

Figure 37. *Cristatella mucedo* zooids (from www.bryozoans.nl).

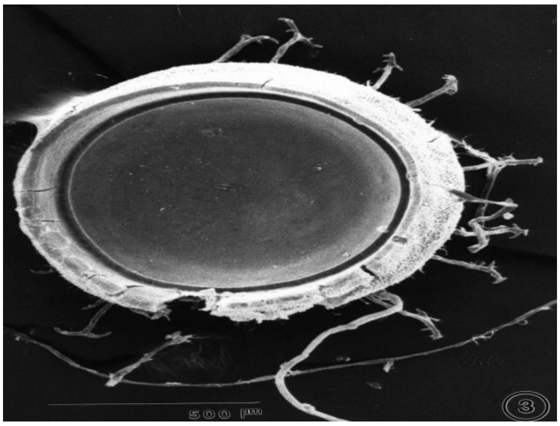

Figure 38. SEM micrograph of *C. mucedo* spinoblast (from www.uleth.ca).

Distribution. *Cristatella mucedo* has a holarctic distribution, occuring in Britain and Ireland in Europe, Asia and North America (Wood and Okamura 2005).

Biology. The species is found on many kinds of substrate but particularly on water plants. It is highly dependent on freshwater and cannot survive in brackish water (Lacourt 1968).

Identification. *Cristatella mucedo* is the only non–tubular species of freshwater bryozoan with a distinctly linear colony, resembling a caterpillar. Small colonies of fewer than ten zooids may be difficult to distinguish from *Lophopodella carteri* (Wood and Okamura 2005).

4.3 Identification key

1 Body wall stiff, shiny, transparent; individual zooids clearly demarcated by internal septa; statoblasts absent –

Gymnolaemata (Subclass Ctenostomata), 2

□ Body wall not as above; internal septa rudimentary and seldom evident; statoblasts formed, especially in zooids attached to substratum, but may be missing in some specimens –

Phylactolaemata, 3

2 Stolon-like tubules connecting upright zooids, tentacles numbering exactly 8; occurring in brackish water –

Victorella pavida (Saville Kent, 1870)

□ Colony lacking stolon-like tubules; zooids branching from each other at nearly right angles; tentacles more than 15 –

Paludicella articulata (Ehrenberg, 1831)

3 Statoblast appears smooth and shiny when dry –

Fredericella sultana (Blumenbach, 1779)

□ Statoblasts not as above –

4

4 Floatoblast dorsal fenestra more than half the statoblast length; both valves convex; colony compact, branches short and fully adherent; sessile statoblast with only weak tubercles on the frontal valve; colony wall never darkly pigmented –

Plumatella casmiana Oka 1907

□ Floatoblast dorsal fenestra much less than half the statoblast length; sessile statoblast not as above; colony form variable, body wall often darkly pigmented –

5

5 Floatoblast fenestra with tubercles: very distinct on the ventral valve, much less on the dorsal valve –

Plumatella emarginata Allman, 1884

□ Floatoblast fenestra lacking tubercles, ventral fenestra with strong reticulation, dorsal fenestra smooth –

6

6 Ventral annulus of floatoblast uniformly narrow in plan view, similar in width at the poles and the equator –

Plumatella geimermassardi Wood & Okamura, 2004

□ Ventral annulus of floatoblast much wider at the poles than at the equator –

7

7 Colony with long, thin, often free branches; zooids widely spaced; statoblast length at least twice the width –

Plumatella fruticosa Allman, 1884

□ Colony branches and statoblasts not as above –

8

8 Overall length of floatoblast greater than 0.45 mm; sessoblasts absent; colony wall thick, gelatinous, colourless –

Hyalinella punctata Hancock, 1850

□ Overall length of floatoblast less than 0.45 mm; sessoblasts may be present; colony wall variable –

9

9 Floatoblast laterally asymmetrical, dorsal fenestra uniformly covered with tubercles; sessoblast with small tubercles on the frontal valve and lateral wall; zooids may fuse to form a massive, sponge-like colony –

Plumatella fungosa Pallas, 1768

□ Floatoblast laterally symmetrical; dorsal fenestra with large tubercles around its periphery, becoming much weaker towards the centre; zooids never fused –

10

10 Floatoblast annulus usually bearing tiny rash-like nodules; otherwise smooth; sessoblast annulus reticulated –

Plumatella repens (Linnaeus 1758)

□ Floatoblast and sessoblast not as above –

11

11 Colony elongate; statoblasts self-inflating and buoyant upon release, with spines radiating from the *margins of the fenestra* (not from the periphery of the annulus) –

Cristatella mucedo Cuvier, 1798

□ Colony sac-shaped; floatoblasts tapering to a point at each end –

Lophopus crystallinus (Pallas, 1768)

Freshwater bryozoology has been a totally neglected field of study in many countries. According to my best knowledge, no published data on the taxonomy of this invertebrate group exists with special reference to Croatia.

This thesis gives a comprehensive description of eleven freshwater bryozoan species that we found in Croatia up to now. The documentation is supported by a wide range of stereomicroscopical and scanning electron microscopical pictures, many of them originating from the material sampled in Croatia. Most important, the work provides a special key for identification of this animal group for Croatia. Therefore, this study represents an essential support for further projects in the field of freshwater bryozoology on the territory of the Republic of Croatia.

In general, only about 88 freshwater bryozoans have been decribed worldwide (Massard and Geimer 2008), a relatively small number in comparison to that of marine living species which is quoted with 5600 or even more, depending on the authors (Todd 2000). In Europe, 19 freshwater bryozoan species have been recorded and the outcome of 11 species described for the territory of the Republic of Croatia is a result which resembles those of surveys in neighbouring countries (Wöss 2004).

6. CONCLUSIONS

- This taxonomic work is based on an ongoing research of six locations in Croatia: Jarun, Crna Mlaka, Žumberak, Plitvice Lakes, Lonjsko Polje and Krka River.
- Altogether, so far eleven species of freshwater bryozoans were found in Croatia, ten phylactolaemates and one gymnolaemate.
- The taxonomic key provided here for the freshwater bryozoans will be an essential basis for all kind of studies in the field of systematics, anatomy, general biology, ecology and evolutionary biology of freshwater bryozoans in Croatia.
- Since this is an initial research on freshwater bryozoology in Croatia, further and thorough systematic investigation is necessary.

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